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Organism — substrate relationship in a small Dutch lowland stream. Preliminary results

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With 1 figure and 3 tables in the text

Introduction

Substrate is one of the most important factors for the micro-distribution of macro-invertebrates in running water (CUMMINS 1966; CUMMINS & LAUFF 1969). The relationship between the micro-distribution of the macro-invertebrates and the substrate composition and distribution is very complex. The preference for a certain substrate can be a secondary effect of food-habit (CUMMINS 1964; CUMMINS & LAUFF 1969), oxygen-need (ERIKSEN 1964; MADSEN 1968), current-velocity (ERIKSEN 1966; WINGFIELD 1939), house-building behaviour (CUMMINS 1964; HANSELL 1968), shelter (HYNES 1970), presence of fine particles obstructing respiration (KEETCH & MORAN 1966), etc.

Much research has been done on organism-substrate relationships, dealing with substrates ranging from fine silt to boulders in various stream-types. However, no detailed information is available on these relationships in lowland streams, where substrate is dominated by sand. The aim of our investigation is to examine the influence of the composition and variation of the substrate on the composition of the typical biocoenoses of lowland streams; we shall also study substrate preferences of animals in relation to the influence of neighbouring substrates and life history stages. Testing and quantifying the relationships between temporal and spatial heterogenity (micro-substrate mosaic patterns) and the composition of the animal communities may lead to greater knowledge of the critical conditions of a lowland stream. This knowledge is needed as a basis for preservation and management of these streams.

Description of the stream

The investigation was carried out in the Snijdersveerbeek, a small stream in the eastern part of the Netherlands (Fig. 1). The stream is fed by iron-rich ground water which seeps into the stream over a length of about 500 m. The stream carries water over at least 1 km, even in very dry summers. The width of the stream bed is 0.4—1.0 m, with some pools up to 2.0 m wide. Depth ranges from 5—30 cm, with an average of 15 cm. In summer, average current-velocity is 10 cm/sec. which rises to 20—30 cm/sec. in winter. Temperature varies from 2 °C in winter to 20 °C in summer. The stream is shaded over its whole length by hedgerows dominated by *Alnus, Salix, Quercus* and *Fagus* or by herb vegetation. In the latter sections some aquatic vegetation occurs in the stream bed: *Myosotis palustris, Mentha aquatica, Veronica beccabunga* and *Glyceria fluitans.* Substrate varies from bare sand, sand mixed and/or covered with fine and/or coarse organic detritus to gravel embedded in loam or sand, with or without organic detritus. In the seep zone, sand is the dominant substrate, while in the lower part of the stream a gravel layer, present in the first 40 cm below the surface, dominates the substrate composition (Fig. 1). Over its whole length the stream bed has a continuously changing mosaic pattern of different substrate-types (Table 1).

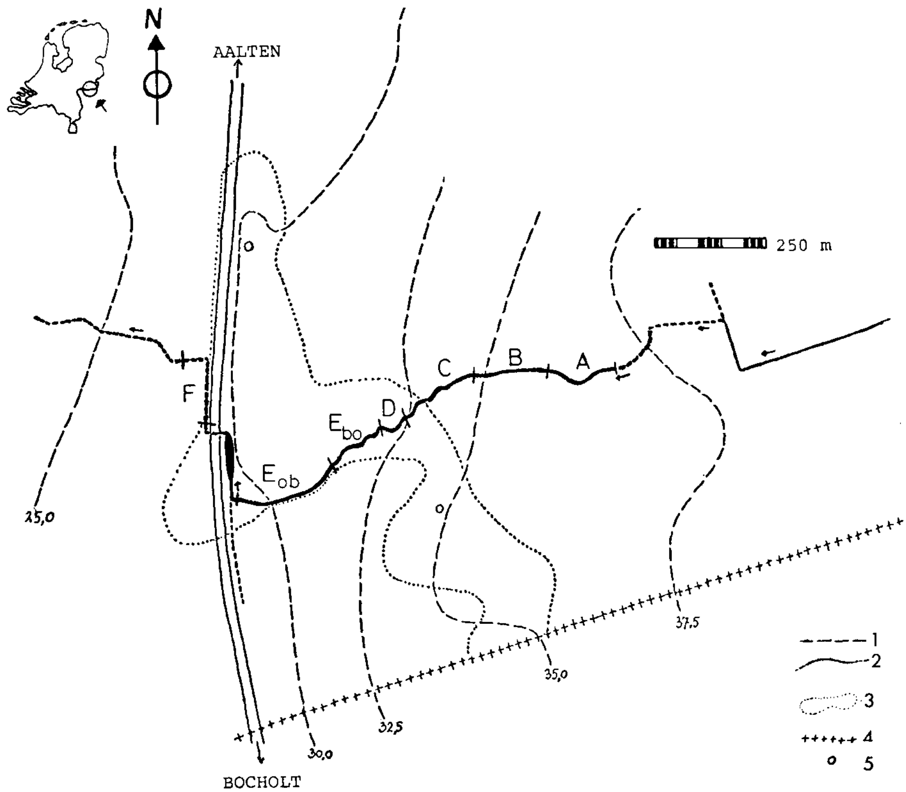

Fig. 1. Map of the Snijdersveerbeek with sections A—F.
1: altitude in m above sea level — 2: the stream (broken line: dry in summer) — 3: gravel in the first 40 cm below the surface — 4: border NL—BRD — 5: old clay starting within 1 m below the surface.

Table 1. Physical characteristics of the 7 sections in the Snijdersveerbeek. S = sand; G = gravel; L = leaves; FD = fine org. detritus; CD = coarse org. detritus; Veg = vegetation; tr = trees; he = herbs; st = stones.

Section	A	B	C	D	E_{bo}	E_{ob}	F
Length (m)	150	200	100	50	200	200	150
Depth (cm)	0—20	5—20	10— 30	5— 30	5— 25	5— 25	0—30
Width (cm)	40—60	40—60	50—100	60—100	60—100	60—100	40—80
Meandering	strong	not	strong	little	little	little	not
Shading by	trees	herbs	tr + he	trees	trees	trees	herbs
Substrate	S; L; FD; CD	S; G; Veg; (CD)	S + G; St; CD; Veg	G+S; St; Veg	G; S; St; L; FD; CD	G; S; St; L; Fd; CD	G; S; St; Veg

Material and methods

Sampling stations (2—3 m long) were chosen in 7 stream sections (Fig. 1). Each station has a substrate pattern typical for the whole section (Table 1). Samples were taken from all substrate types present at a station and a detailed sketch was made of the distribution of the substrates. Samples of the bottom-material containing the macro-invertebrates were taken with a micro-macrofauna-shovel designed by the senior author, which will be described elsewhere (TOLKAMP in prep.). This shovel is 10 cm wide, 15 cm deep and 10 cm high and it is pushed through the substrate over a length of 15 cm, 3 cm deep. Samples had to be thus small because of the changes in substrate composition over short distances. Leaf-packs were sampled by hand.

Animals were hand-picked in the laboratory. From Sept. 1975 until April 1977, samples were taken monthly. In this paper only the (preliminary) results of the first 83 samples of the total of 384, taken from Sept. 1975 until Jan. 1976 will be presented.

Substrates were analysed following CUMMINS' (1962) suggestions. The results of the analyses were expressed with indices based on WENTWORTH phi-values of the first quartile (Q_1), median (M_d) and third quartile (Q_3) according to the system for the interpretation of grain-size analysis of DOEGLAS (1968).

Seven substrate-types were distinguished, based on the particle-size analyses and the field observations:

1. Sand (M_d positive): a) bare
2. Sand (M_d positive): b) covered and mixed with fine organic detritus
3. Sand (M_d positive): c) covered and/or mixed with coarse organic detritus
4. Sand (M_d positive): d) covered and or mixed with fine and coarse organic detritus
5. Gravel (M_d negative): a) bare
6. Gravel (M_d negative): b—d) covered and/or mixed with fine and/or coarse organic detritus
7. Leaves and/or coarse organic detritus without mineral substrate.

Results and discussion

In the 384 samples ca. 60,000 animals were found, distributed over 149 taxa. The differences in species composition and numbers between the 7 stream sections are marked and will be described elsewhere (TOLKAMP in prep.). The relationship of several taxa to the studied substrates was expressed as the Index of Representation (I. R.) (HILDREW & TOWNSEND 1976). Table 2 gives the I. R.-values for some of the taxa in relation to the 7 substrate types. Distribution of a taxon is considered not to be random when chi^2 is more than the 5 % point for chi^2 with 6 degrees of freedom ($Q = 15.59$). In Table 2 the largest positive I. R.-values are printed in italics. They can be regarded as indices of over-representation of a taxon in the substrate concerned. Large negative I. R.-values of course indicate under-representation. Taxa in Table 2 marked with an asterisk have I. R.-values significant for almost all substrates, which indicates a negative binominal distribution.

The fauna associated with bare sand (S_a) is rather poor in individuals, which agrees with the conclusions of MACKAY (1969), HYNES (1970), PERCIVAL & WHITEHEAD (1930) and SPRULES (1947). However, there are a few species that prefer this habitat: red Chironomini (mainly *Polypedilum breviantennatum* TSHERNOVSKIJ, 1949 and *Stictochironomus* sp.), and *Limnophila* sp., although the latter is found less frequently.

Table 2. Substrate preference of several taxa in the Snijdersveerbeek, expressed as I.R.-value. Italisized I.R.-values indicate over-representation. p ‹ 0.05; Q = 12.59.

Main-substrate		Sand				Gravel		Leaves	Total
Detritus		a	b	c	d	a	b—d	b—d	
Number of samples		23	11	7	6	25	5	6	83
Taxon	number of ind.								chi²
Oligochaeta	191	— 2.19	— 1.45	+ _8.44_	— 2.64	— 2.30	— 2.51	— 2.64	103.73
Pisidium	92	— 3.27	+_15.98_	— 1.71	— 2.19	— 4.12	— 0.23	— 2.58	297.62
*_Gammarus pulex_	1844	—18.05	— 0.98	+_11.99_	+_24.92_	—16.31	+ 4.36	+_25.27_	2014.71
Ephemera danica	41	— 2.48	+ 0.67	— 0.25	— 1.14	— 1.52	+_11.15_	— 1.72	137.66
Baetis vernus	192	— 6.33	— 2.67	+ _8.15_	— 2.12	+ 6.60	— 0.46	— 3.73	175.81
Limnephilidae	71	— 3.76	— 2.42	+ 0.82	+ _3.92_	+ 0.56	+ 0.83	+ _3.92_	52.32
Lithax obscurus	52	— 3.53	— 2.24	— 0.66	— 1.94	+ _6.40_	+ 0.49	+ 0.91	63.78
Plectrocnemia conspersa	31	— 1.91	+ 1.43	— 0.38	+ _3.18_	— 2.07	— 1.37	+ _4.52_	42.50
Sericostoma personatum	17	— 0.33	+ 0.50	+ 0.48	+ 0.69	— 1.38	+ _2.95_	— 1.11	12.90
Red Chironomini	307	+_18.86_	— 2.30	— 3.71	— 3.44	— 8.89	— 3.83	— 4.71	502.40
*_Eukiefferiella_ gr. _discol._	182	— 6.68	— 4.91	— 3.66	— 0.04	— 6.73	— 3.01	+_40.20_	1752.68
Corynoneura	55	— 2.62	— 2.33	— 0.30	+ 3.52	— 3.82	— 1.82	+_14.55_	254.32
*_Brillia modesta_	116	— 4.32	— 3.92	— 2.49	+ 1.59	— 5.74	— 1.89	+_30.25_	1003.73
Prodiamesa olivacea	83	— 2.71	+ 0.30	+_15.12_	+ 0.41	— 5.00	+ 0.89	— 2.45	267.98
*Tanytarsini	2774	—14.78	+_51.65_	+_16.41_	+ 6.60	—26.45	— 5.66	— 5.47	3960.72
Ptychoptera	42	+ 0.40	+ 1.88	+ _6.62_	— 1.17	— 3.28	— 0.96	— 1.74	63.60
Dicranota bimaculata	69	— 1.17	+ 1.61	— 0.75	+ _3.14_	— 4.34	— 0.57	— 0.44	33.72
Limnophila	156	+ 1.94	— 1.47	+ 1.06	— 0.38	— 1.60	+ _4.44_	— 3.36	40.72
Ceratopogonidae	42	— 1.07	+ _2.72_	+ 1.20	+ 1.70	— 0.46	— 0.96	— 1.17	15.39
Helodes minuta	71	— 4.44	— 3.07	— 2.45	— 1.38	— 4.62	+ 0.83	+_25.55_	711.88

Sand mixed and covered with fine organic detritus (S_b) is preferred by *Pisidium* sp.. Tanytarsini also have a preference for S_b, although further identification of this tribe revealed that *Micropsectra* gr. *praecox* accounts for this preference, while other species (at least 7) show other preferences.

Although not all chironomids were identified to species level, 48 taxa were distinguished. The composition of the chironomid fauna in S_b showed strong correspondence with the fauna of the sand-mud-detritus substrate described by LINDEGAARD-PETERSEN (1972).

Sand with coarse organic detritus (S_c) and sand with both fine and coarse detritus (S_d) is preferred by 9 taxa of which 3 (*Gammarus pulex* L., *Plectrocnemia conspersa* CURTIS and Limnephilidae spp. [dominated by young *Chaetopteryx villosa* FABRICIUS]) show over-representation in leaf-packs too.

Bare gravel (G_a) is preferred by *Lithax obscurus* (HAG.), while *Baetis vernus* CURTIS is about equally distributed on G_a and S_c · Gravel with detritus ($G_{b—d}$) is preferred by *Ephemera danica* MÜLL, and *Limnophila* sp.. *Limnophila* sp. prefers $G_{b—d}$ above S_a. Although *Sericostoma personatum* SPENCE showed an almost random distribution over the substrate-types, over-representation on gravel with detritus is found. This agrees with the preference for stony substrates reported by WALLACE (1977).

Leaves support a very rich community of species. Some species (*Eukiefferiella* gr. *discoloripes* and *Helodes minuta* larvae) were found in such small numbers in other substrates that the conclusion is justified that they are probably restricted to this habitat.

The influence of life-stage on the micro-distribution of macro-invertebrates has been reported by several authors (MACKAY 1969; CSOKNYA & HALASY 1974; OTTO 1976; EGGLISHAW 1969). This phenomenon will be investigated for all taxa found in the Snijdersveerbeek and some other streams. Only the results concerning the influence of life-stage on the preference of *Ephemera danica* MÜLL. are presented here. *Ephemera* was present in 89 of 280 samples taken from Sept. 1975 until Jan. 1977, with a total number of 345 individuals. I. R.-values concerning the distribution over the mineral substrates (leaves as substrate was not included as only one nymph was found in this habitat) are arranged in Table 3. The I. R.-values for different nymphal size-classes show that small nymphs are almost equally distributed on sand and gravel, while larger nymphs prefer gravel.

PERCIVAL & WHITEHEAD (1926) observed that *Ephemera danica* digs more readily in coarse substrates (grain size over 3 mm), which agrees with the results from Tables 2 and 3. They also found that the typical habitat of *Ephemera danica* consists of a mixture of sand-grains with a considerable proportion (59—82 %) with a diameter from 0.05 to 1.0 mm, present in depositing areas. This agrees with our conclusion that smaller nymphs prefer sand with fine detritus, although considering the total population of *Ephemera danica*, the preference for gravel is slightly higher. However, only half of our samples contained more than 50 % of the 0.05—1.0 mm fraction and only one third of our samples contained more than 75 % of this fraction. PERCIVAL & WHITEHEAD (1930) did find *Ephemera danica* in gravel substrates, but they did not find sand and gravel substrates neighbouring in the same stream. These data underline the necessity

Table 3. Substrate preference of different size-classes of *Ephemera danica*. Italisized I.R.-values indicate over-representation. $p < 0.05$; $Q = 11.07$.

Main-substrate		Sand				Gravel		Total
Detritus		a	b	c	d	a	b—d	
Number of samples		79	39	20	34	80	28	280
size (mm)	ind.							chi²
1— 5	78	—4.05	+*2.17*	+0.18	+0.82	—2.60	+*7.59*	86.22
5—10	146	—3.30	+*4.36*	+*2.96*	+0.06	—1.66	+0.63	41.83
10—15	88	—2.98	—0.07	—0.91	+*1.32*	+*1.77*	+*1.42*	16.56
15—20	22	+0.72	—0.62	+1.14	—1.02	+0.68	—1.48	5.90
20—27	11	—0.62	—1.24	+1.36	—1.16	—0.08	+*2.77*	12.77
1—27	345	—5.51	+*3.46*	+2.09	+0.64	—1.27	+*4.85*	72.18

of a more refined division of substrate-types, based on the fractions of each grain size and the amount of organic detritus present in and on the mineral substrate.

Interpretation of the data will be performed by computer (factor analysis) characterizing substrates by individual grain-size fractions and the amount, nature and degree of breakdown of the organic detritus. Conclusions of the field investigation will be tested in the laboratory in a model stream. Final checking will be performed by testing colonization of artificial substrates in the field.

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